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FOR

METHOD AND APPARATUS FOR SIMPLIFIED PATTERNING OF FEATURES IN A COMPUTER AIDED DESIGN (CAD) MODEL

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METHOD AND APPARATUS FOR SIMPLIFIED PATTERNING OF FEATURES IN A COMPUTER AIDED DESIGN (CAD) MODEL

FIELD OF INVENTION

The invention relates to the field of computer aided design (CAD). More specifically, the invention relates to simplified patterning of features in a three-dimensional solid geometry piece.

BACKGROUND OF THE INVENTION

Computer aided design (CAD) programs have allowed users to design various parts in "virtual" space before the parts ever reach a manufacturing stage. As CAD programs have become more powerful, parts modeled in "virtual" space (i.e., CAD models) have become more true to life. Often times, these CAD models are also referred to as three-dimensional (3-D) solid models or as solid models because of the fact that they are 3-D geometry pieces with solid properties, such as volume, faces that define the boundary of the three-dimensional solid geometry piece, weight, and so forth. Because the models have solid properties, solid features, such as solid featured forming patterns, may be incorporated into the solid models.

For example, a user may design a solid model of a speaker cover having small hole features arranged in a pattern to protect the delicate components while allowing sound to travel through the cover. Another example may be a solid model of a heatsink having fin features arranged in a particular pattern to increase the

effective surface area for heat transfer. In both examples, the number of features forming the desired pattern may be numerous.

Often times, underlying these features are 2-D parametric sketches that geometrically define the features. For the example of small holes in the speaker covering, each of the small holes may be formed by a 2-D sketch of a small hole whereby the 2-D sketch of the small hole is extruded to perform a solid operation with the speaker covering. That is, the small hole is extruded and subtracted from the speaker covering forming the necessary holes. A change in the 2-D parametric sketch affects the solid model and vice versa.

Accordingly, during or subsequently, the user may change the design of the solid model, thereby affecting the surface on which the features may be patterned. In order to compensate for the change in the solid model, the user may be required to change the pattern of the features to ensure optimum utilization of the features. Furthermore, the user may change the design of the features themselves, thereby further affecting the pattern of the features.

Accommodating changes in design, in particular, the changes in design that affect the pattern of particular features may be difficult. For example, if the shape and/or size of the speaker cover is modified, the hole features that make up the pattern are required to be individually modified to ensure that the desired density of hole features is maintained within the boundary of the speaker cover. Modifying the hole features may involve individually modifying each 2-D sketch underlying the hole feature. Furthermore, the number of hole features may increase or decrease based at least upon the changes in shape and/or size of the speaker cover (i.e., the

changes in the boundary of the patterned hole features). In the example of the heatsink, the pattern of the fin features may correspond to a desired effective surface area. Modifications in size and/or shape of the heatsink may affect the desired effective surface area because the boundary of the patterned fin features may change. However, in order to maintain the desired density of the fin features (i.e., the effective surface area), individual fin features may need to be modified in order to compensate for changes in the size and/or shape of the heatsink. Again, modifying individual fin features may involve modifying each 2-D sketch underlying each fin feature.

Parametric solid modeling capabilities of CAD programs may aid a user making necessary modifications to features and patterns in relation to design changes of a solid model. However, often times, correlating the features and the pattern with the solid model involves building numerous mathematical relationships between the features, in particular, the underlying 2-D sketches, the pattern, and the solid model. Building the numerous mathematical relationships may make designing features for a particular pattern very time consuming, and even minor errors in the mathematical relationships need to be corrected for the parametric solid modeling capabilities to function properly and provide the desired patterned results.

Often times, in order to reduce initial design time, a designer will forego building numerous mathematical relationships, and instead, proceed to design features and patterns without relationships on a solid model. However, if modifications of the solid model are desired, the designer may be required expend

much more time to redesign the features, in particular, the underlying 2-D sketches, and patterns to accommodate the changes.

BRIEF DESCRIPTION OF DRAWINGS

The invention is illustrated by way of example and not by way of limitation in the figures of the accompanying drawings, in which the like references indicate similar elements and in which:

FIGURE 1 illustrates a block diagram of one embodiment of a mechanical design application for facilitating simplified modification of patterns of features in a solid model, in accordance with the present invention;

FIGURE 2 illustrates an exemplary solid model having a pattern of features wherein the pattern may be automatically modified, in accordance with one embodiment of the invention;

FIGURE 3 illustrates a top view of a solid model having a pattern of features whereby the pattern and its feature may be described in terms of dimensions for describing an embodiment of the invention;

FIGURE 4 illustrates an exemplary menu with which a user may enter various inputs for patterns, in accordance with one embodiment of the invention;

FIGURE 5 illustrates a modification of a solid model and its affect on a pattern;

FIGURE 6 illustrates simplified modification of a pattern on a solid model, in accordance with one embodiment of invention;

FIGURE 7 illustrates simplified modification of a pattern on a solid model, where the pattern is optimized, in accordance with another embodiment of invention;

FIGURE 8 illustrates an example of an alternative shape of a solid model with which an embodiment of the invention may be practiced;

FIGURE 9 illustrates operational flow for simplified modification of patterns of features in a solid model, in accordance with one embodiment of the invention; and

FIGURE 10 illustrates one embodiment of a computer system suitable to be programmed with the mechanical design application of the invention.

DETAILED DESCRIPTION OF THE INVENTION

In the following description, various aspects of the invention will be described. However, it will be apparent to those skilled in the art that the invention may be practiced with only some or all described aspects. For purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the invention. However, it will also be apparent to one skilled in the art that the invention may be practiced without the specific details. In other instances, well-known features are omitted or simplified in order not to obscure the invention.

Parts of the description will be presented in terms of operations performed by a computer system, using terms such as data, flags, bits, values, characters, strings, numbers and the like, consistent with the manner commonly employed by those skilled in the art to convey the substance of their work to others skilled in the art. As well understood by those skilled in the art, these quantities take the form of electrical, magnetic, or optical signals capable of being stored, transferred, combined, and otherwise manipulated through mechanical and electrical components of the computer system, and the term computer system includes general purpose as well as special purpose data processing machines, systems, and the like, that are standalone, adjunct or embedded.

Various operations will be described as multiple discrete steps in turn, in a manner that is most helpful in understanding the invention. However, the order of description should not be construed as to imply that these operations are necessarily

order dependent. In particular, these operations need not be performed in the order of presentation.

Reference throughout this specification to “one embodiment” or “an embodiment” means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. Thus, the appearances of the phrases “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment or invention. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

For the purposes of describing the invention, 3-D computer aided design (CAD) models will be referred to as solid models. That is, the 3-D CAD models may have solid properties, such as, but not limited to, volume, weight, and density. Additionally, solid operations, such as subtract, unite, and the like, may be performed utilizing the 3-D CAD models. Furthermore, it should be appreciated that the 3-D CAD models may be of the parametric type, where various aspects of the 3-D CAD models may be updated utilizing underlying 2-D sketches, and so forth.

In various embodiments of the invention, simplified modification of patterns of features in a solid model is facilitated. This and other advantages will be evident from the disclosure.

FIGURE 1 illustrates a block diagram of one embodiment of a mechanical design application for facilitating simplified modification of patterns of features in a solid model, in accordance with the present invention. In **FIG. 1**, mechanical design

application **100** includes an end user interface **102**, a design engine **104**, and a design database **106**. The design engine **104** includes, in particular, a pattern determination engine **108**, in accordance with the invention. Together, the elements cooperate to modify patterns of features corresponding to modifications in the solid model, in accordance with one embodiment of the invention. The modification to the solid model may be in the form of modifications to underlying sketches of the solid model.

In **FIG. 1**, the end user interface **102** operates to graphically display and receive input, from a user, of a solid model under the control of the design engine **104**. Under the control of the design engine **104**, the design database **106** operates to store solid model information for modifying a pattern of features. In particular, the pattern determination engine **108** utilizes various inputs to automatically modify patterns of features in response to modifications of the solid model. Except for the teachings of the present invention incorporated in the pattern determination engine **108**, the mechanical design application **100** is intended to represent a broad range of CAD software known in the art, including but not limited to Autodesk Inventor™, available from Autodesk, Inc. of San Rafael, California. Additionally, as alluded to earlier, the mechanical design application **100** may include parametric software components to provide parametric functionality, such as, but not limited to, 2D Dimensional Constraint Manager available from D-Cubed, Ltd. of Cambridge, England.

FIGURE 2 illustrates an exemplary solid model having a pattern of features wherein the pattern may be automatically modified, in accordance with one

embodiment of the invention. Shown in **FIG. 2** is a solid model **200** having a pattern **210** comprised of a number of features **220**. The pattern **210** may be of a particular dimension and shape according to a design intent of a user (not shown). For example, the pattern **210** may be of a particular dimension and shape to facilitate passage of sound through each feature **220** of the solid model **200**.

It should be appreciated that for the purposes of describing the invention, the solid model **200**, the pattern **210**, and the feature **220** that make up the pattern **210** may be parametrically related (i.e., modifications to underlying 2-D sketches, solid operations, and so forth will affect each other). Furthermore, since the pattern **210** may be described as having dimension and shape, in order to describe the invention, references will be made to dimensions of the pattern and its feature. In particular, the invention will be described in terms of dimensional relationships of the pattern, feature, and the solid model upon which the feature pattern is included. Accordingly, shown in the figures to follow, dimensions having "*" will denote dimension that have been affected by the practice of the invention. Furthermore, for the purpose of describing the invention, modification in dimensions may correspond to modification in the underlying 2-D sketch (i.e., a reduction in length of a geometry piece corresponds to new dimension that defines the reduced length).

FIGURE 3 illustrates a top view of a solid model having a pattern of features whereby the pattern and its feature may be described in terms of dimensions for describing an embodiment of the invention. Shown in **FIG. 3** is a top view of the solid model **200** having the pattern **210** of feature **220** (shown in **FIG. 2**). Six critical sides **1-6** as shown bound the solid model **200**. Critical dimension **301** defines

length of side **1**, critical dimension **302** defines length of side **2**, critical dimension **303** defines length of side **3**, and critical dimension **304** defines length of side **6**. Together, critical dimensions **301-304** define the boundary of the solid model **200**. Furthermore, as will be described below, the critical dimensions **301-304** may be utilized to calculate a surface area having the pattern **210**.

Critical dimensions **310 & 311** also define the feature **220** that make up the pattern **210**. Critical dimension **312** defines an inter-feature distance in the y-direction (Y-IFD), while critical dimension **313** defines inter-feature distance in the x-direction (X-IFD). Critical dimension **314** defines distance between the feature **220** and side **6** (boundary value 1), critical dimension **315** defines distance between the feature **220** and side **1** (boundary value 2), critical dimension **316** defines distance between the feature **220** and side **2** (boundary value 3), critical dimension **317** defines distance between feature **220** and side **3** (boundary value 4), and critical dimension **318** defines distance between feature **220** and side **4** (boundary value 5). Together, critical dimensions **310-318** define the shape of the pattern **210**.

Illustrated in **FIG. 3**, is a top view of the solid model **200**. However, as alluded to previously, it should be appreciated by those skilled in the relevant art that the illustration of solid model **200** of **FIG. 3** may be an illustration of the underlying 2-D parametric sketch(s) utilized to generate the solid model **200**. Accordingly, each feature **220** may also be illustrated in **FIG. 3**, as underlying 2-D parametric sketches utilized to generate the feature **220**.

As shown in **FIG. 3**, in order to describe the invention, the shapes of the solid model **200** and the pattern **210** are rectangular. Furthermore, feature **220** is square

in shape and instanced. However, it should be appreciated by those skilled in the relevant art that the solid model **200**, the pattern **210**, and the feature **220** may be of any shape, such as, but not limited to, circular or any combination of shapes.

The critical dimensions shown in **FIG. 3** are exemplary to describe the invention whereby modification of the pattern **210** may be simplified, in accordance with one embodiment of the invention. Accordingly, in the description of the invention to follow, the practice of the invention may be described utilizing dimensional changes.

FIGURE 4 illustrates an exemplary menu with which a user may enter various inputs for patterns, in accordance with one embodiment of the invention. Shown In **FIG. 4**, pattern menu **400** includes a first field for receiving an input corresponding to a first direction for the pattern to be generated, such as, but not limited to, the x-direction. The pattern menu **400** includes a second field to receive a second direction **415** for the pattern **210** to be generated, such as, but not limited, to the y-direction. Furthermore, included in the first and second fields **410 & 415** are fields/icons to receive inputs, such as count and spacing that define number of instances and the spacing between the features within the pattern **210**. As will be described in further detail below, the first and second fields **410 & 415** may be utilized as the initial settings of the pattern **210**. However, the first and second fields **410 & 415** may vary based at least upon the other fields/icons of the pattern menu **400**, in accordance with one embodiment of the invention.

The pattern menu **400**, in particular, includes a third field **420** for receiving a boundary input. The third field **420** includes fields/icons to receive inputs regarding

maximum and minimum values. The boundary maximum value **421** that the user may enter corresponds to a maximum desired distance between a feature **220** and a boundary **1-6**. Accordingly, the boundary minimum value **422** corresponds to a minimum desired distance between a feature **220** and a boundary **1-6**.

Two additional fields, included in the pattern menu **400**, are a tolerance 1 field **430** and a tolerance 2 field **440**. The tolerance 1 field **430** may correspond to an inter-feature distance in the x-direction (X-IFD **313**) whereby the user may enter a desired minimum and maximum distance between features in the x-direction. The tolerance 2 field **440** may correspond to an inter-feature distance in the y-direction (Y-IFD **312**) whereby the user may enter a desired minimum and maximum distance between features in the y-direction.

Additionally, included in the pattern menu **400** may be a graphical representation of an optimize icon button **450**, which when selected by the user, the tolerance field 1 **430** and the tolerance 2 field **440** are grayed-out (i.e., non-selectable). As will be described in detail below, the tolerance field 1 **430** and tolerance field 2 **440** are grayed-out because if both the selection of optimize icon button **450** and a modification of the solid model **200** is received, in response, the pattern determination engine **108** automatically optimizes the pattern **210** for the solid model **200**, in accordance with one embodiment of the invention.

As shown in **FIG. 4**, the pattern menu **400** is for a rectangular pattern. However, as alluded to earlier, it should be appreciated by those skilled in the relevant art that pattern menu **400** may be for any shape of feature, such as, but not limited to, a circular pattern. Additionally, even though maximum and minimum

fields are shown, it should be appreciated that the user may enter a maximum without having to enter a minimum and vice versa.

For the purpose of describing the invention, the exemplary pattern menu **400** will be continuously referred to because as will be described in further detail, as the various inputs are received, via the user entered fields/icons, the pattern determination engine **108** simplifies modification of various aspects of the pattern **210**, in accordance with various embodiments of the invention.

FIGURE 5 illustrates a modification of a solid model and its affect on a pattern. Shown in **FIG. 5**, the length of one side **1** has been modified; in particular, the critical dimension **310** of side **1** has a new dimension ***501** corresponding to the change in length of side **1**. Accordingly, the critical dimension **303** of side **3** has also changed to a new dimension ***503**. As shown in **FIG. 5**, side **2** is no longer present because the initial settings of the pattern menu **400** (i.e., first and second fields **410 & 415**) interfere with a new position of side **2**. Furthermore, because side **2** is removed, dimension **316** is no longer present (i.e., no distance to define).

Shown in **FIG. 5**, before the invention is practiced, the modification to the solid model **200** will cause the undesired affect shown in **FIG. 5**. As alluded to earlier, because the solid model is parametric, as described previously, the modification may involve a modification to the underlying 2-D parametric sketch as well as a solid operation, such as, but not limited to, moving a face to result in the new dimension ***501** for length of side **1**.. Accordingly, the solid model shown in **FIG. 5** may be an updated solid model after the user has performed the modification(s).

FIGURE 6 illustrates simplified modification of a pattern on a solid model, in accordance with one embodiment of invention. Shown in **FIG. 6**, the pattern **210** on solid model **200** has been automatically modified, in accordance with one embodiment of the invention. As shown in **FIG. 6**, in response to the modification to the solid model **200**, the pattern determination engine **108** retrieves various inputs entered by the user through the pattern menu **400**. From the various inputs, the pattern determination engine **108** determines if the pattern **210** needs to be modified. Upon identifying the modifications that need to be made , pattern determination **108** causes other functional blocks of design engine **104** to modify the pattern **210** resulting in an automatically modified pattern **610** shown in **FIG. 6**.

Referring temporarily back to **FIG. 4**, the automatically modified pattern **610** may be caused by the user entering various inputs via certain fields/icons, such as, but not limited to, the user entering a minimum value in the boundary field **450**.

Accordingly, in **FIG. 6**, in response to the input, the pattern determination engine **108** analyzes if any modification needs to be made to pattern **610**. For example, if it is determined that a row of features need to be removed, the pattern determination engine **108** causes other functional blocks of design engine **104** to remove a row of features. For the example in which a row of features needs to be removed, the pattern determination engine **108** determines that the boundary minimum value **422** (shown in **FIG. 4**) is not met for critical side **2**. That is, there is an interference between the critical side **2** and the feature **220** causing critical side **2** to be removed, as shown in **FIG. 5**. Accordingly, in **FIG. 6**, the pattern determination engine **108** determines that the interfering row of features needs to be removed

resulting in the pattern and its features being continuously included within the boundary of the modified solid model.

Furthermore, in response to removing the row of features that does not meet the boundary minimum value **422** in the boundary field **420**, the pattern determination engine **108** causes other functional blocks of design engine **104** to modify the Y-IFD **312**, in order to have an automatically modified Y-IFD ***612**.

Shown in **FIG. 6**, in response to the input, pattern determination engine **108** determines that if the boundary value 1 **314** (shown in **FIG. 3**) is to be modified to ensure that the boundary minimum value **422** in the boundary field **420** is met (both shown in **FIG. 4**), the boundary value 1 **314** between the feature **220** and side **6** has to be modified to a new boundary value 1' ***614**. Additionally, in order to maintain alignment between features, the pattern determination engine **108** determines that the boundary value 4 **317**, between the feature **220** and side **3**, has to be modified to a new boundary value 4' ***617**. Furthermore, because a row of features **220** has been removed, the pattern determination engine **108** determines that boundary value 3 **316**, between the feature **220** and side **2**, needs to be modified a new boundary value 3' ***616**. As alluded to previously, the pattern determination engine **108** may determine the necessary modifications, the Y-IFD ***612**, new boundary value 1' ***614**, new boundary value 3' ***616**, and new boundary value 4' ***617**, of the automatically modified pattern **610** based at least upon the inputs of pattern menu **400** (shown in **FIG. 4**).

Upon determining these necessary modifications, pattern determination engine **108** causes other functional blocks of design engine **104** to effectuate the

changes to the solid model reflecting the necessary modification to the critical dimensions.

In the one embodiment, the pattern determination engine **108** determined that Y-IFD dimension ***612**, new boundary value 1' ***614**, between the feature **220** and side **6**, and new boundary value 3' ***616** between the feature **220** and side **2** need to be modified to maintain their equivalency. In another embodiment, pattern determination engine **108** also automatically determines Y-IFD ***612**, new boundary value 1' ***614**, and new boundary value 3' ***616** may be different based at least upon the user entering various inputs via certain fields/icons of pattern menu **400**. Depending on the results of these analyses, pattern determination engine **108** invokes other functional blocks to modify the solid model to reflect the necessary changes, if any.

As a result, a pattern is automatically updated in response to modifications in a solid model.

In summary, in response to the user inputs, pattern determination engine **108** evaluates the various critical dimensions to determine whether any modification is necessary to conform to the inputs provided by the user. Upon determining one or more necessary modifications to the critical dimensions, pattern determination engine **108** further evaluates the impact of the necessary modifications, to determine if complementary modifications to each of the other critical dimensions are necessary to maintain consistency and/or equivalency. Pattern determination engine **108** iteratively repeats this process until the analysis converges, and it is

determined that all critical dimensions settle to a set of new consistent mutually conforming values.

FIGURE 7 illustrates simplified modification of a pattern on a solid model, where the pattern is optimized, in accordance with another embodiment of invention. Shown in **FIG. 7**, the solid model **200** continues to have the solid model modified dimensions of ***501 & *503**. However, the resulting pattern shown in **FIG. 7**, is in response to receiving a user selection of optimize **450** via pattern menu **400** (shown in **FIG. 4**). From the various inputs and the optimize input **450**, the pattern determination engine **108** determines a ratio between the surface area of the solid model, within which the pattern is included, and the total surface area that the features occupy (i.e., surface area of each feature multiplied by the number of features). Upon determining the ratio, the pattern determination engine **108** determines if the pattern **210** needs to be modified. Based at least upon the various inputs and the determined ratio, the pattern determination engine **108** identifies the modifications that need to be made to the pattern **210**, in order to maintain the ratio. Upon identifying the modifications that need to be made, the pattern determination engine **108** causes other functional blocks of design engine **104** to modify the size of the feature **220**, while maintaining the shape of the pattern **210**.

As shown in **FIG. 7**, the modified dimensions ***501 & *503** changes a surface area **701**, having the pattern **210**, and in response to the changes, the pattern determination engine **108** analyzes if any modification needs to be made to pattern **210**, in particular, to features **220** (shown in **FIG. 2**) of the pattern **210**. For example, if it is determined that the features **210** need to be modified, the pattern

determination engine **108** causes other functional blocks of design engine **104** to modify the size of the feature **220** resulting in a new feature **720** having new feature dimensions ***710 & *711**, as shown in **FIG. 7**. Furthermore, as shown in **FIG. 7**, in response to new features **720** having new feature dimensions ***710 & *711**, pattern determination engine **108** determines if other related dimensions, such as the critical dimensions **312-318** (shown in **FIG. 3**) also need to be modified. Upon determining that other related dimensions, such as critical dimensions **312-318** (shown in **FIG. 3**) need to be modified, pattern determination engine **108** causes other functional blocks of design engine **104** to modify critical dimensions **312-318**, that define the pattern **210**, to new dimensions ***712-*718**, as shown in **FIG. 7**.

As a result, simplified modification of patterns in a three-dimensional (3-D) solid geometry piece is facilitated, where the patterns are optimized.

FIGURE 8 illustrates an example of an alternative shape of a solid model with which an embodiment of the invention may be practiced. As alluded to earlier, the shape of a solid model may differ from the rectangular shape as previously described, and accordingly, a pattern of features may differ based at least upon the shape of the solid model. Illustrated in **FIG. 8**, is a top view of a solid model having a circular shape **800**. A number features of a circular shape **810** forms a substantially circular pattern **805**, as illustrated. Each of the features of circular shape **810** may be defined by a diameter **820**. Position of each of the features of circular shape **810** may be defined by an angle **825**. Additionally, a radial distance **830** may define a distance from the features of circular shape **810** and a boundary **840** of the solid model having the circular shape **800**.

In **FIG. 8**, if the solid model having the circular shape **800** is modified, such as, but not limited to, the boundary **840** being enlarged. In response, based at least upon the various inputs of pattern menu **400** (shown in **FIG. 4**), the pattern determination engine **108** determines what modification, if any, needs to be made in view of the modifications being made to the solid model, as earlier described (i.e., by analyzing various critical dimensions). As previously described, upon identifying the modifications that need to be made, pattern determination engine **108** causes other functional blocks of design engine **104** to effectuate the desired changes, such as to modify the circular pattern **805** and/or the features of circular shape **810** based at least upon the inputs entered by the user through the pattern menu **400** and by analyzing various critical dimensions. For example, in **FIG. 8**, the modification may be a change in diameter **820**, a change in the number of features of circular shape **810**, and so forth.

As a result, the teachings of the invention are not limited to simple shapes such as squares or rectangles, but apply to radial as well.

FIGURE 9 illustrates operational flow for simplified modification of patterns of features in a solid model, in accordance with one embodiment of the invention. For the illustrated embodiment, pattern determination engine **108** (shown in **FIG. 1**) is programmed in an event driven model (i.e., pattern determination engine **108** is designed to be executed in a system environment where various event notification services are available from the operating system). One example of such an operating system suitable for practicing the invention is the Windows® operating system, available from Microsoft Corporation of Redmond, Washington. In alternate

embodiments, pattern determination engine **108** may be implemented in other programming approaches known in the art.

At operational block **910**, the pattern determination engine **108** receives an input corresponding to generation of a pattern in a computer aided design (CAD) geometry piece. The pattern comprises of a number of features included within a boundary of the CAD geometry piece. As described previously, the input may be through a pattern menu.

At operational block **915**, the pattern determination engine receives an indication of modification to the CAD geometry piece. In response, the pattern determination engine **108** causes other functional blocks of design engine **104** to automatically modify the CAD geometry piece and its boundary based at least upon the received indication, at operational block **920**.

Additionally, in response to the modification of the CAD geometry piece, the pattern determination engine **108** determines what modification, if any, needs to be made in view of the modifications being made to the solid model, as earlier described (i.e., by analyzing the various critical dimensions). Upon so determining, pattern determination engine **108** causes other functional blocks of design engine **104** to effectuate the desired changes to the pattern and the number of features to be continuously included within the boundary of the modified CAD geometry piece, at operational block **925**. The features or the pattern is modified based at least upon the modified CAD geometry piece and the received input.

As a result, simplified modification of patterns of features in a solid model is facilitated.

FIGURE 10 illustrates one embodiment of a computer system suitable to be programmed with the mechanical design application of the invention. As shown, for the illustrated embodiment, computer **1000** includes processor **1002**, processor bus **1006**, high performance I/O bus **1010** and standard I/O bus **1020**. Processor bus **1006**, and high performance I/O bus **1010** are bridged by host bridge **1008**, whereas I/O buses **1010** and **1020** are bridged by I/O bus bridge **1012**. Coupled to processor bus **1006** is cache **1004**. Coupled to high performance I/O bus **1010** are system memory **1014** and video memory **1016**, against which video display **1018** is coupled. Coupled to standard I/O bus **1020** are disk drive **1022**, keyboard and pointing device **1024**, and communication interface **1026**.

These elements perform their conventional functions known in the art. In particular, disk drive **1022** and system memory **1014** are used to store permanent and working copies of the mechanical design system incorporated with the teachings of the invention. The permanent copy may be pre-loaded into disk drive **1022** in factory, loaded from distribution medium **1032**, or down loaded from a remote distribution source (not shown). Distribution medium **1032** may be a tape, a CD, and DVD or other storage medium of the like. The constitutions of these elements are known. Any one of number implementations of these elements known in the art may be used to form computer system **1000**.

In general, those skilled in the art will recognize that the invention is not limited by the details described, instead, the invention can be practiced with modifications and alterations within the spirit and scope of the appended claims.

The description is thus to be regarded as illustrative instead of restrictive on the invention.

Thus, an improved way of modifying patterns of features in solid models is disclosed.